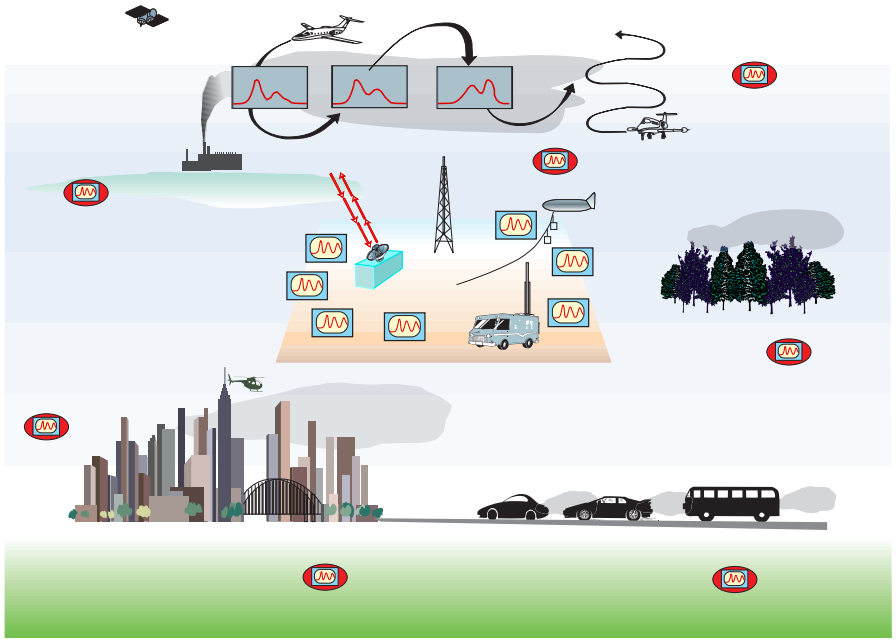
THE DEPARTMENT OF ENERGY'S

TROPOSPHERIC AEROSOL PROGRAM - TAP

AN EXAMINATION OF AEROSOL PROCESSES AND PROPERTIES



American Geophysical Union, Fall Meeting, San Francisco, December 12-17, 1999

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The Department of Energy's Tropospheric Aerosol Program (TAP)
An Examination of Aerosol Processes and Properties

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Fine particles (diameter < 2.5 μm) exhibit elevated concentrations in industrialized and surrounding regions as a result of emissions of particles and of precursor gases followed by gas-to-particle conversion in the atmosphere. Many of the responsible emissions are associated with energy related activities. Fine particles are thought to be harmful to human health and deleterious to the environment through visibility reduction and deposition of acids and other substances to the surface. Fine particles are thought also to influence climate through light scattering and modification of cloud properties. Although many features of the aerosol life cycle are understood in a general way, much understanding is lacking of the details of the processes governing the mass loading, composition, and microphysical properties of aerosols, understanding that is necessary to develop effective strategies to reduce their adverse environmental effects efficiently from an energy and economic standpoint. A major new research program, the Tropospheric Aerosol Program (TAP, http://www.tap.bnl.gov) is being designed by the Department of Energy and the scientific community to provide such understanding. TAP will consist of four closely linked components: 1) Field measurement campaigns, typically within 200 km of major source regions, focusing on aerosol composition as a function of size and the processes that govern the evolution of size and composition; 2) Development and application of next-generation instrumentation for characterization of aerosols and precursor gases; 3) Laboratory and theoretical investigations focusing on aerosol transformation mechanisms; and 4) modeling of the atmospheric evolution of aerosol chemical and microphysical properties, and model evaluation making use of data from the field measurement campaigns. TAP is viewed as a component of a larger national aerosol program, contributing to and leveraging aerosol research efforts in other federal and state agencies, industry, and academia. This talk outlines the TAP objectives and approach.

The Importance of Tropospheric Aerosols

Fine particles are associated with:

- Acute and chronic pulmonary disease
- Visibility impairment
- Acid deposition
- Shortwave energy budget

Ambient Air Quality Standards

New standards for particulate matter of diameter less than 2.5 μm (PM-2.5 standards).

Mass loading not to exceed:
15 μg m-3 (annual mean)
65 μg m-3 (24-h, 98th percentile)

The DOE Context for TAP

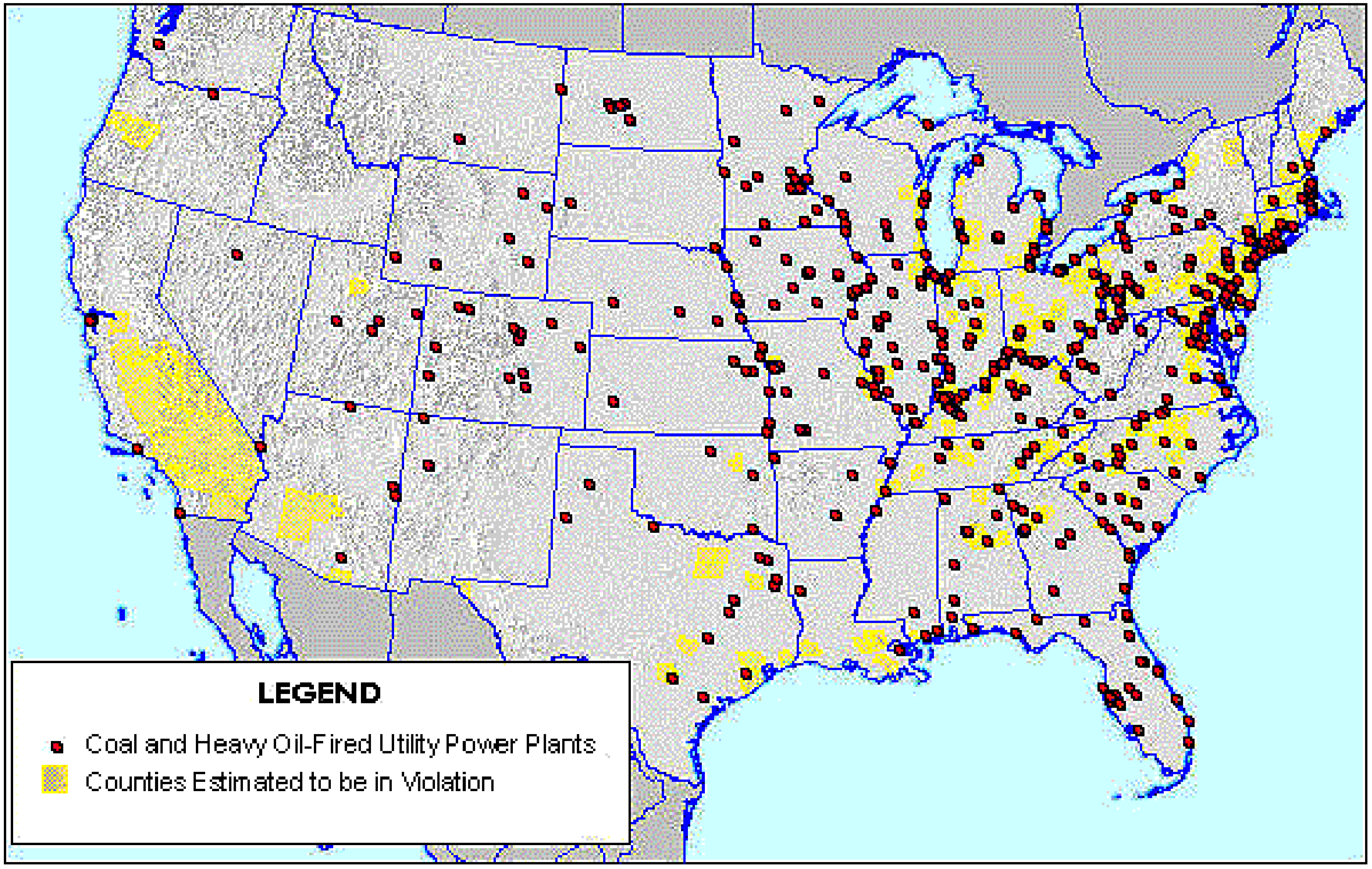
PM 2.5 particles . . .

"May pose respiratory problems for certain portions of the population, and for this Administration, there is no higher priority than protecting the health of our citizens . . .

"At the same time, if our clean air regulations are to be fair and scientifically-sound, we need to understand much better the linkage between the levels of these pollutants in the atmosphere and their sources, both human and natural."

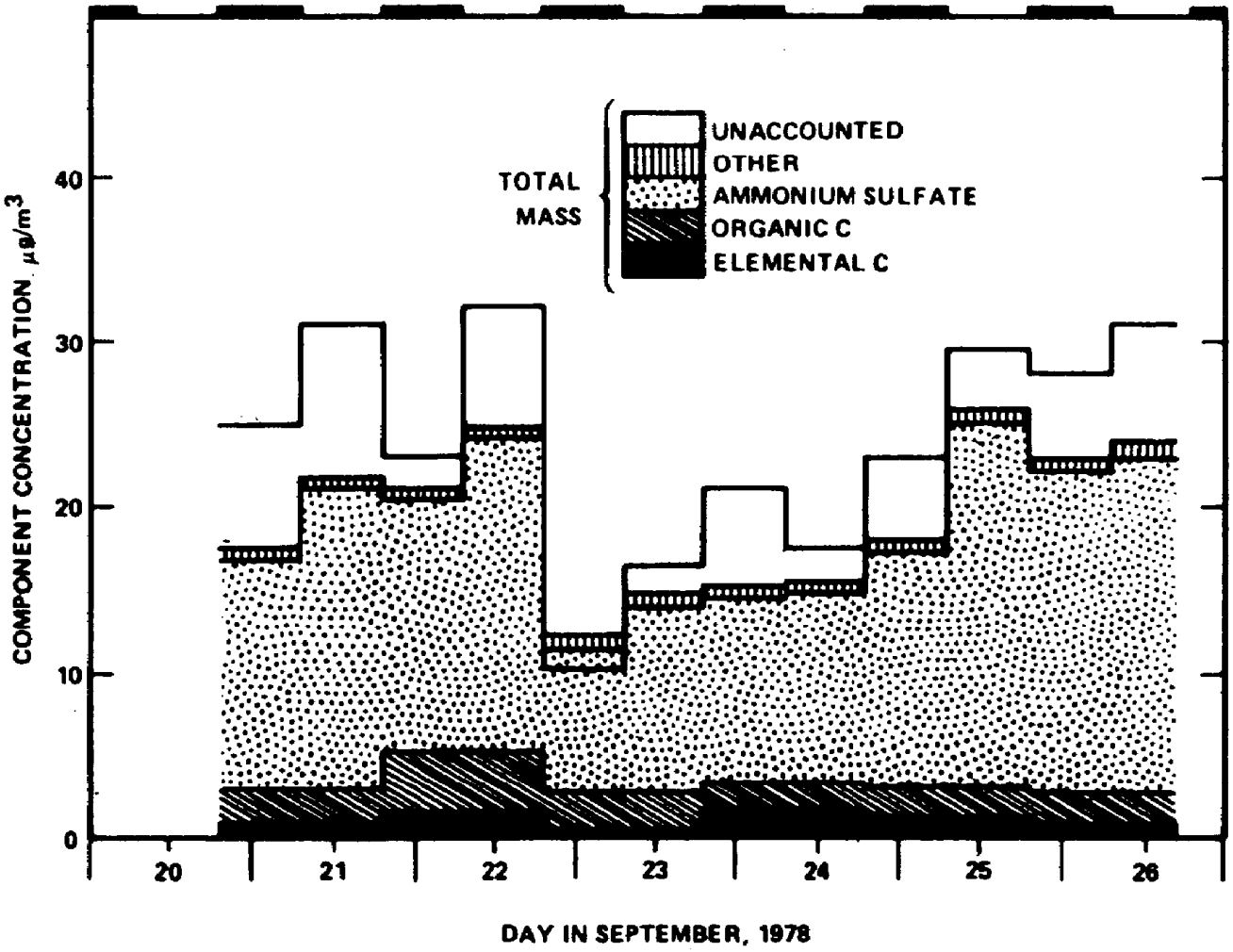
- Secretary of Energy Bill Richardson

Locations of Coal-Fired and Heavy Oil-Fired Plants Relative to Potential Non-Attainment Counties



AEROSOL COMPOSITION

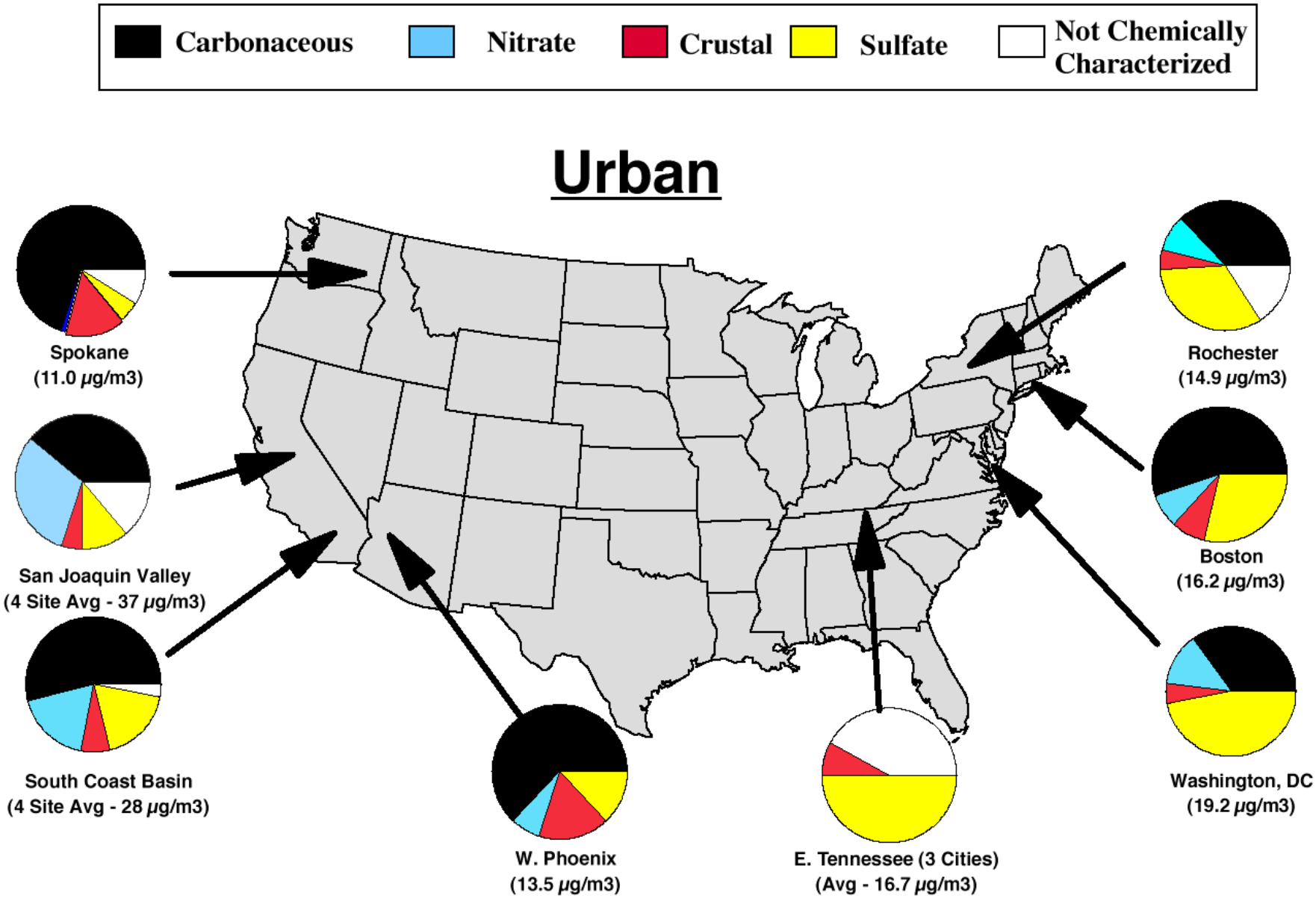
Great Smoky Mountains (U.S.), September 1978



New Annual-Average
Fine Particle Standard

Stevens *et al.*, *Environ. Sci. Technol.*, 1980

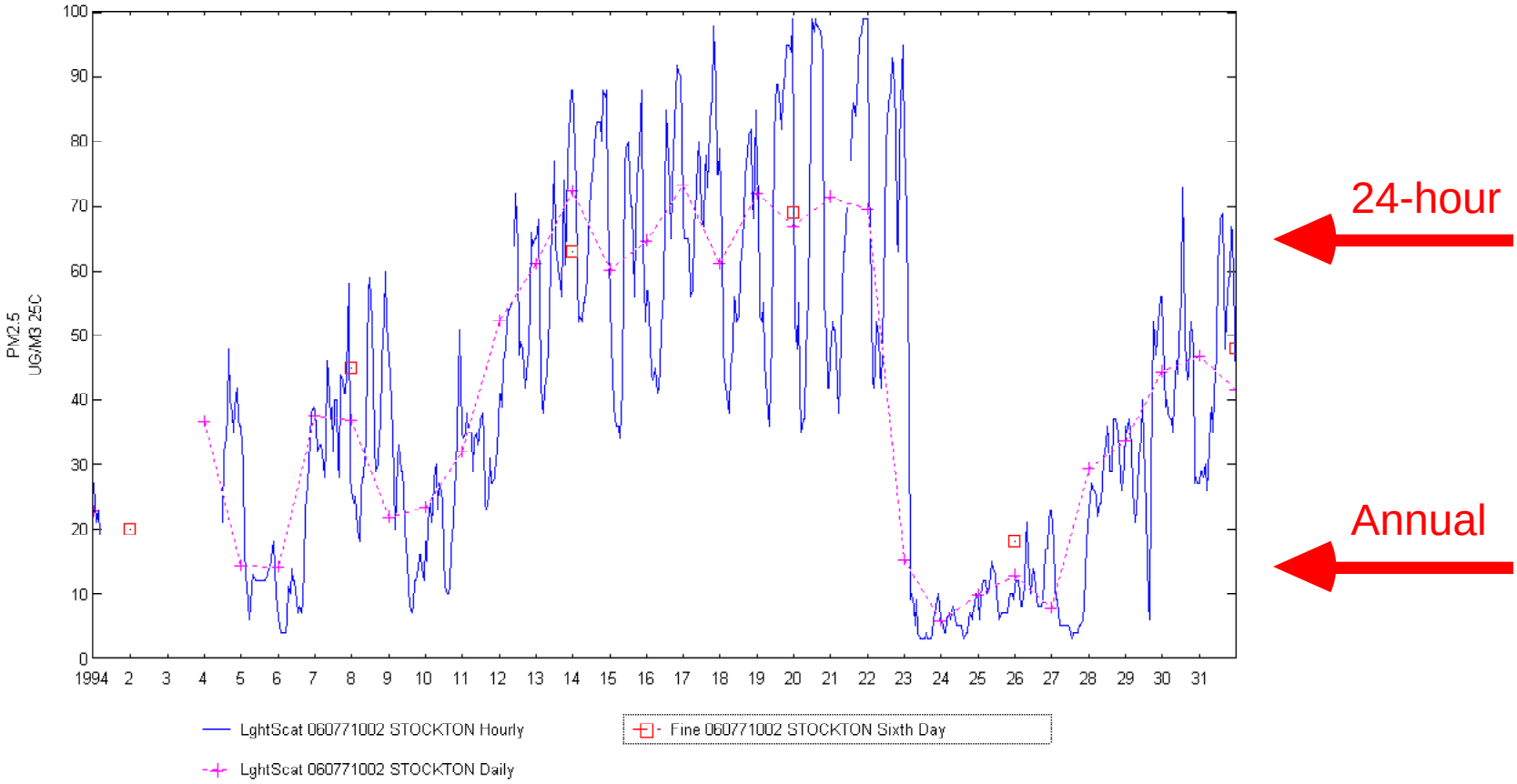
DEPENDENCE OF AEROSOL COMPOSITION ON LOCATION



EPA, *National Air Quality and Emissions Trends Report, 1997*, 1998

TIME SERIES OF LIGHT SCATTERING COEFFICIENT AND FINE PARTICLE MASS

STOCKTON CA



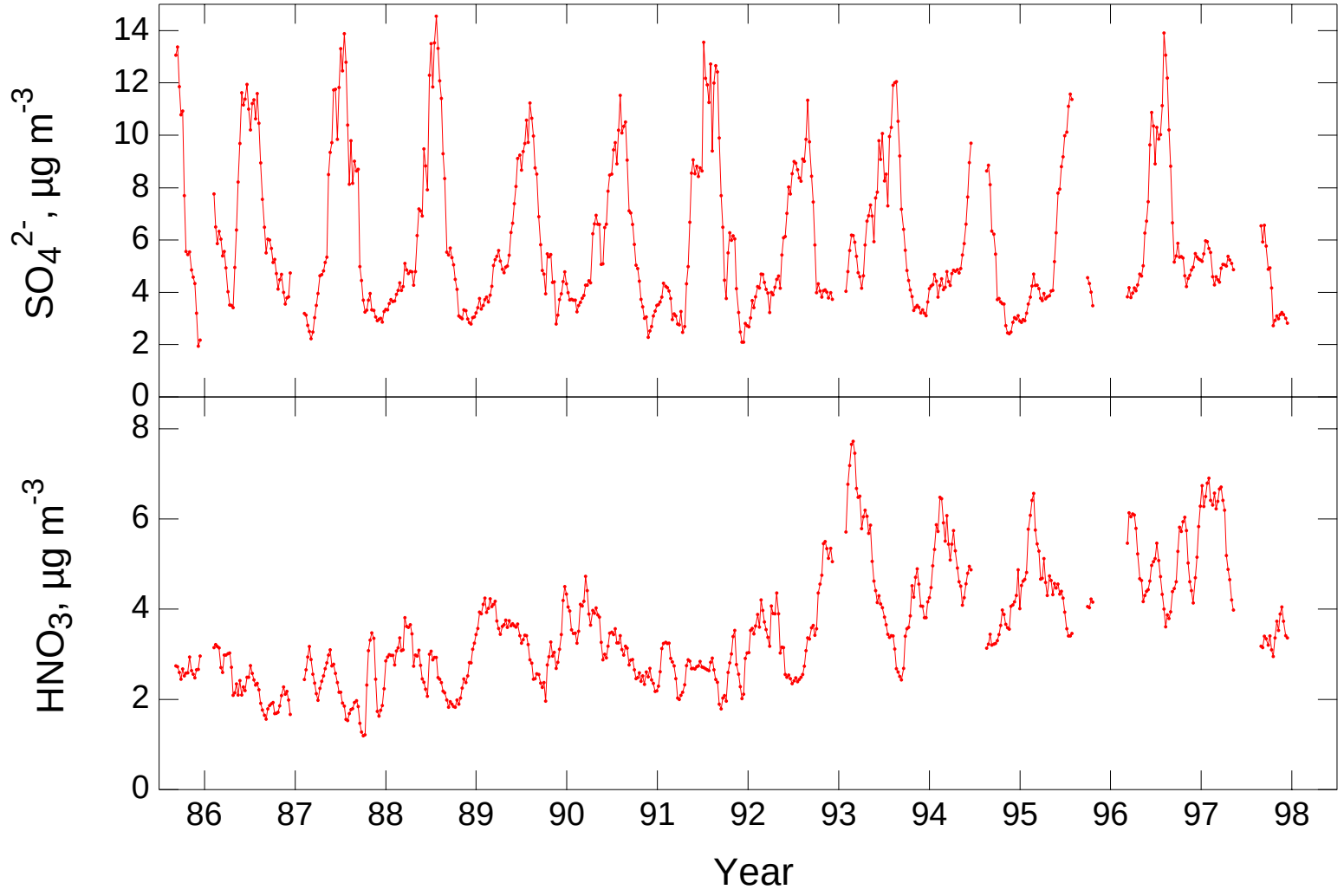
Husar, 1997

Time series of light scattering coefficient is scaled to fine particle mass by daily averages.

SULFATE AND NITRIC ACID CONCENTRATIONS

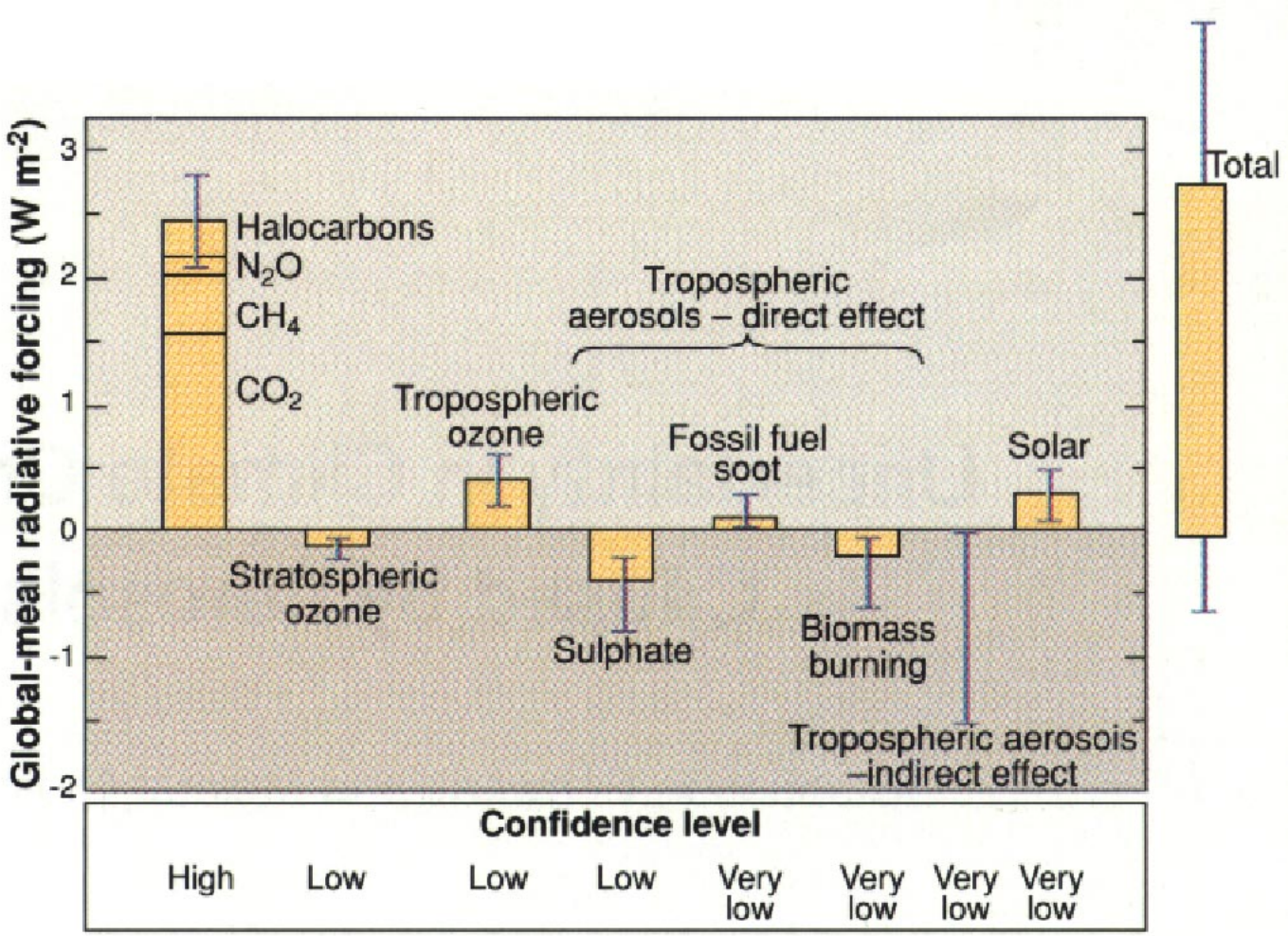
Time Series over the 80's and 90's at State College PA

Smoothed running mean of five 1-week samples



Data from B. Hicks, NOAA Air Resources Lab

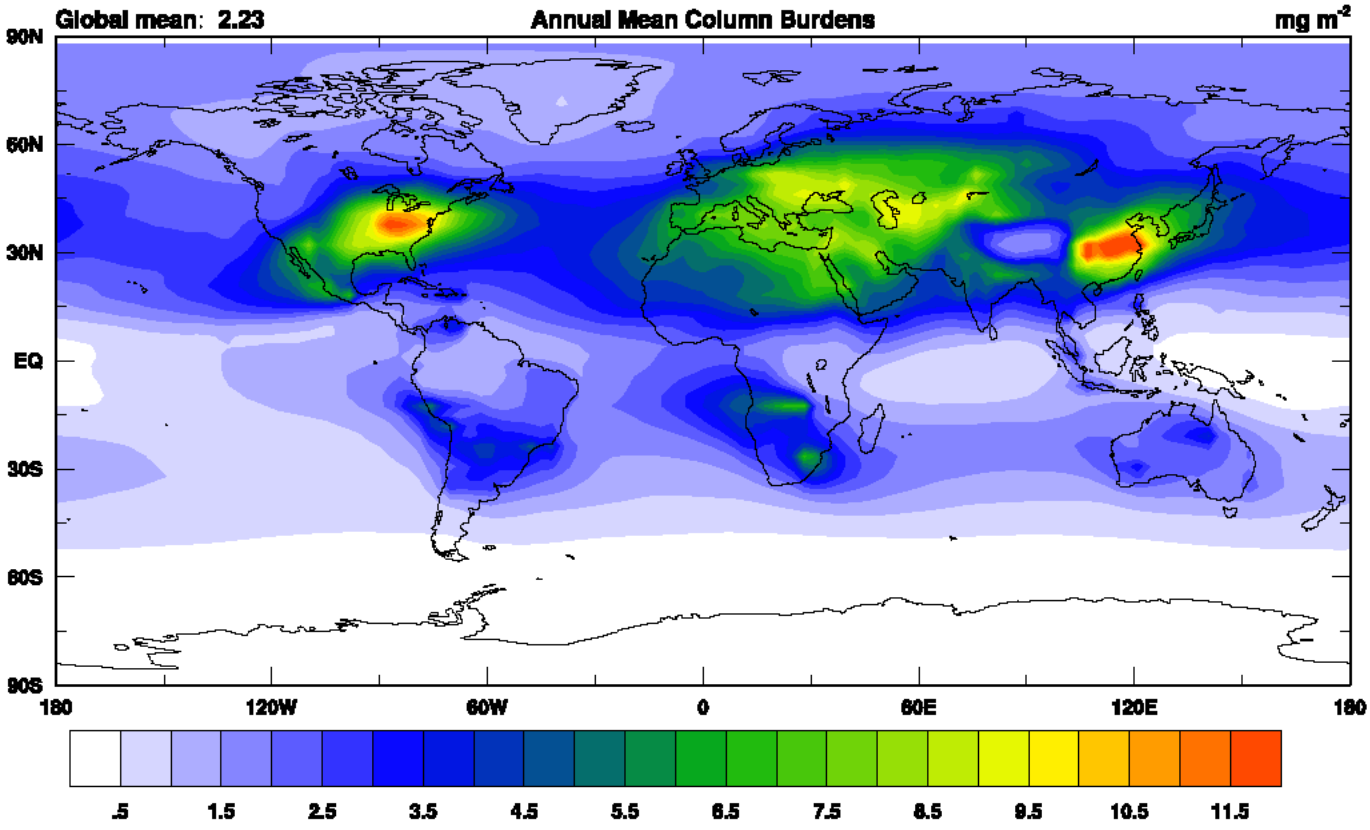
UNCERTAINTY IN AEROSOL FORCING DOMINATES UNCERTAINTY IN CLIMATE FORCING OVER THE INDUSTRIAL PERIOD

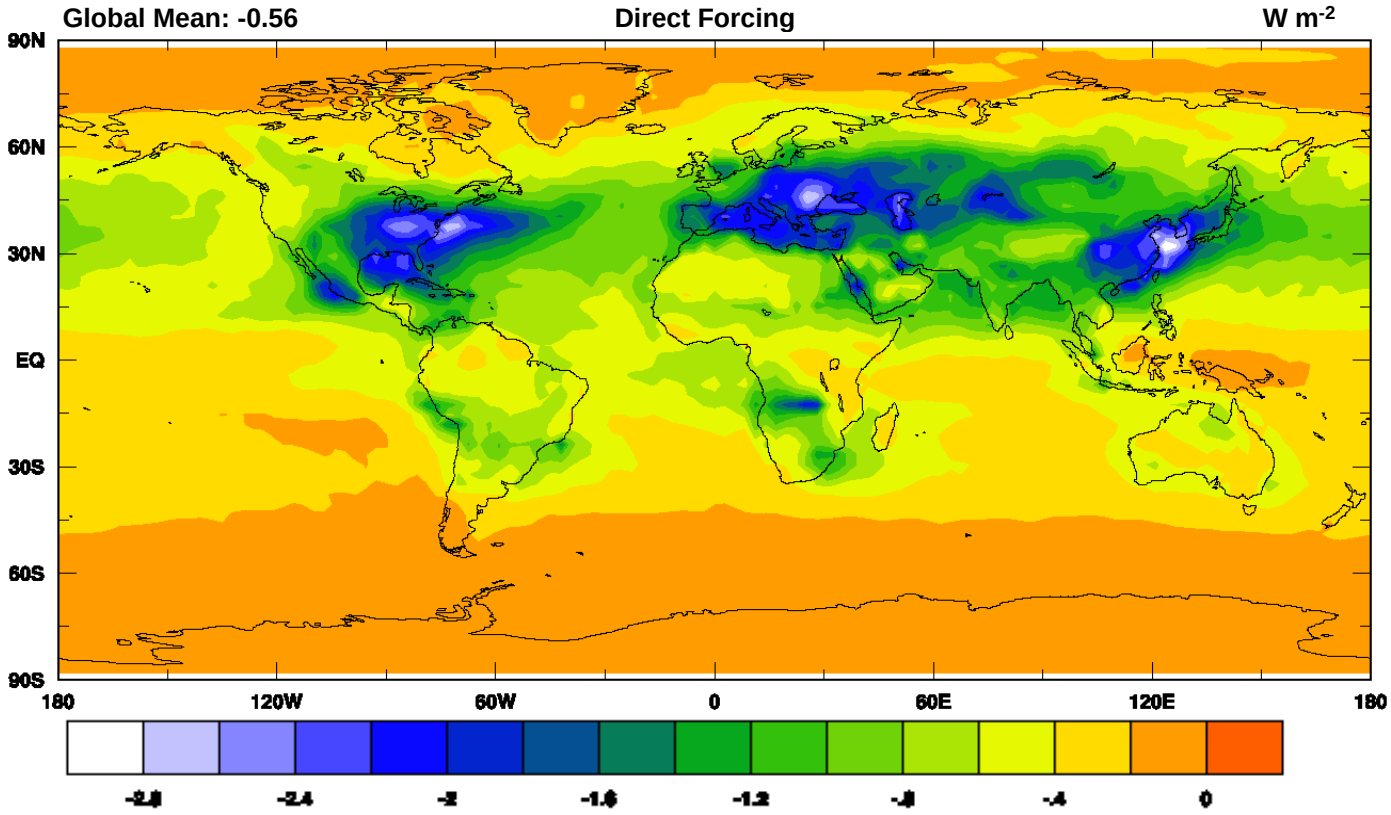


- Schwartz and Andreae (Science, 1996), after IPCC (1996)

ANTHROPOGENIC SULFATE COLUMN BURDEN AND DIRECT FORCING

BNL Sulfate Model in NCAR CCM3





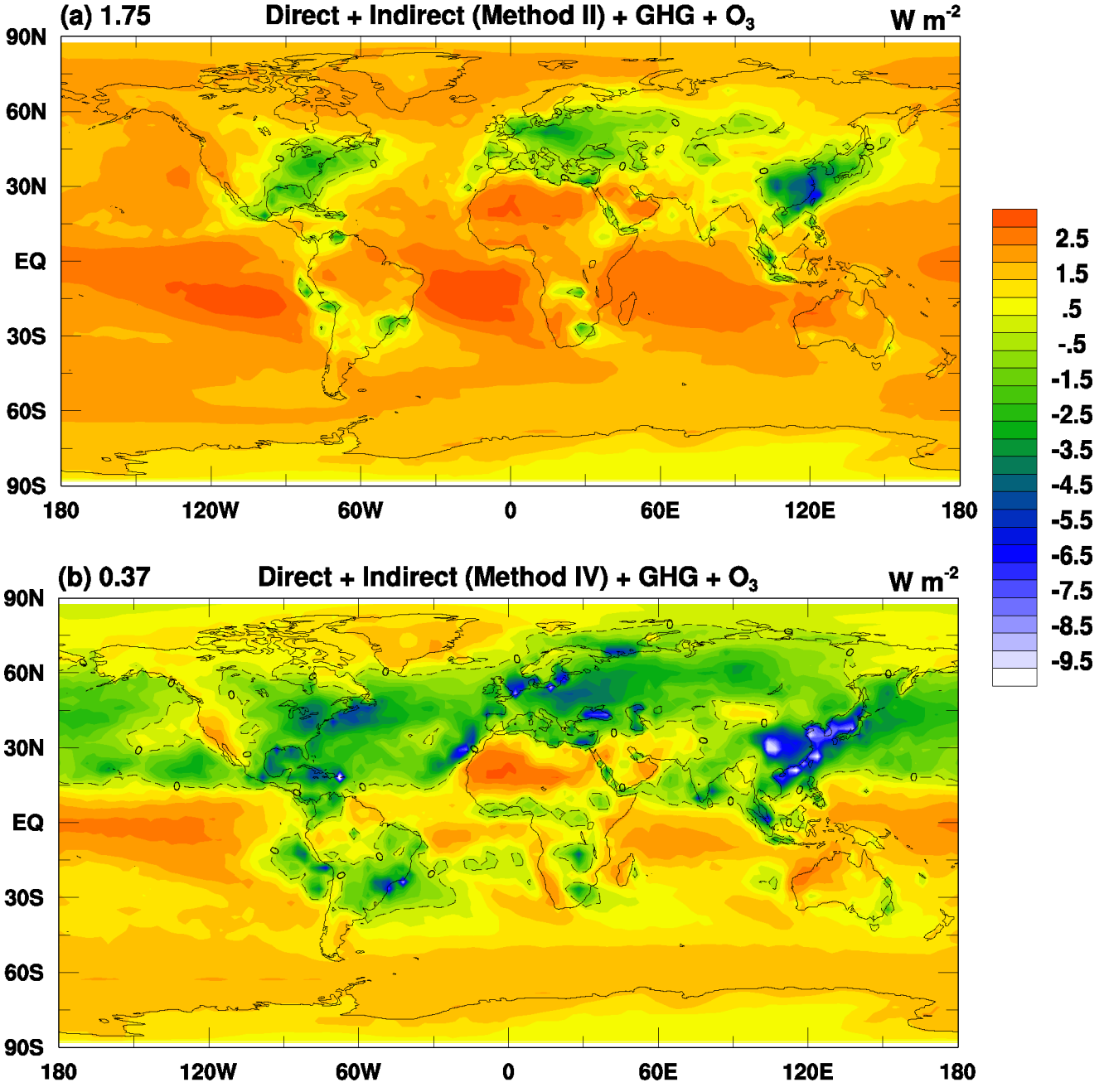
Kiehl et al., JGR, in press

SHORTWAVE FORCING, ANNUAL AVERAGE

BNL Sulfate Model in NCAR CCM3

GHG's + O_3 + Sulfate (Direct and Indirect)

Two Formulations of Cloud Droplet Concentration



Kiehl et al., JGR, in press

TAP Requirement

Ability to quantitatively describe...

and represent in models...

the loading and properties of tropospheric aerosols...

with known and reasonable uncertainties.

TAP Objective

Develop the fundamental scientific understanding required to construct tools for simulating the life cycle of tropospheric aerosols. . .

The ***processes*** controlling their mass loading, composition, and microphysical properties . . .

All as a function of time, location, altitude, and ambient conditions.

This understanding should be capable of being represented in models suitable on a variety of geographical scales, from tens to thousands of kilometers.

Developing and evaluating these models will be a key contribution of TAP.

TAP Approach

The TAP approach will be to conduct closely linked . . .

Field Studies

Instrumentation Development/Advanced Characterization

Laboratory and Theoretical Studies, and

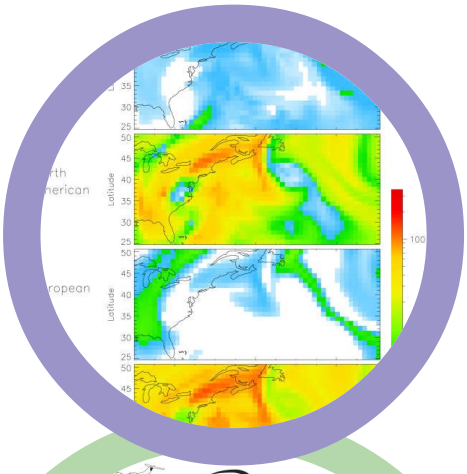
Model Development and Evaluation

Focused on the ***processes*** controlling formation, growth, chemical composition, transport, and deposition of tropospheric aerosols.

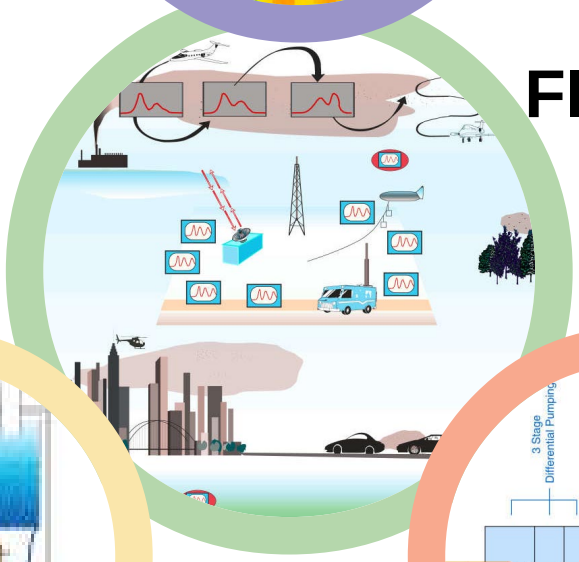
In carrying out these tasks TAP will work closely with other programs in DOE and in other Federal and state agencies, and in the private sector, directed to related aerosol issues.

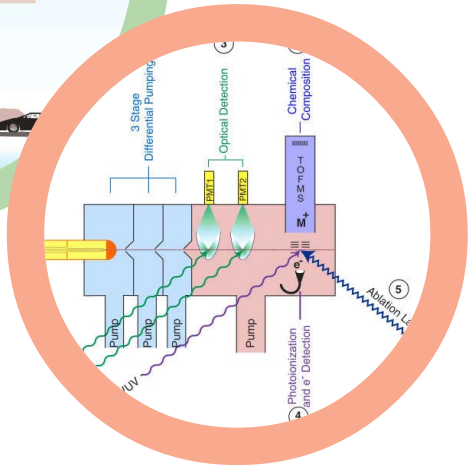
COMPONENTS OF TAP RESEARCH

MODELING



FIELD





LABORATORY & THEORY

INSTRUMENTATION & ADVANCED CHARACTERIZATION

Objectives of TAP Field Studies

- Describe ***local properties*** of ambient tropospheric aerosol:
  - Mass Loading
  - Microphysical properties
  - Composition (function of size)
- Describe ***spatial variation*** of ambient tropospheric aerosol:
  - Regional scale (200 km)
  - Vertical (5 km)

cont'd . . .

Objectives of TAP Field Studies (*cont'd*)

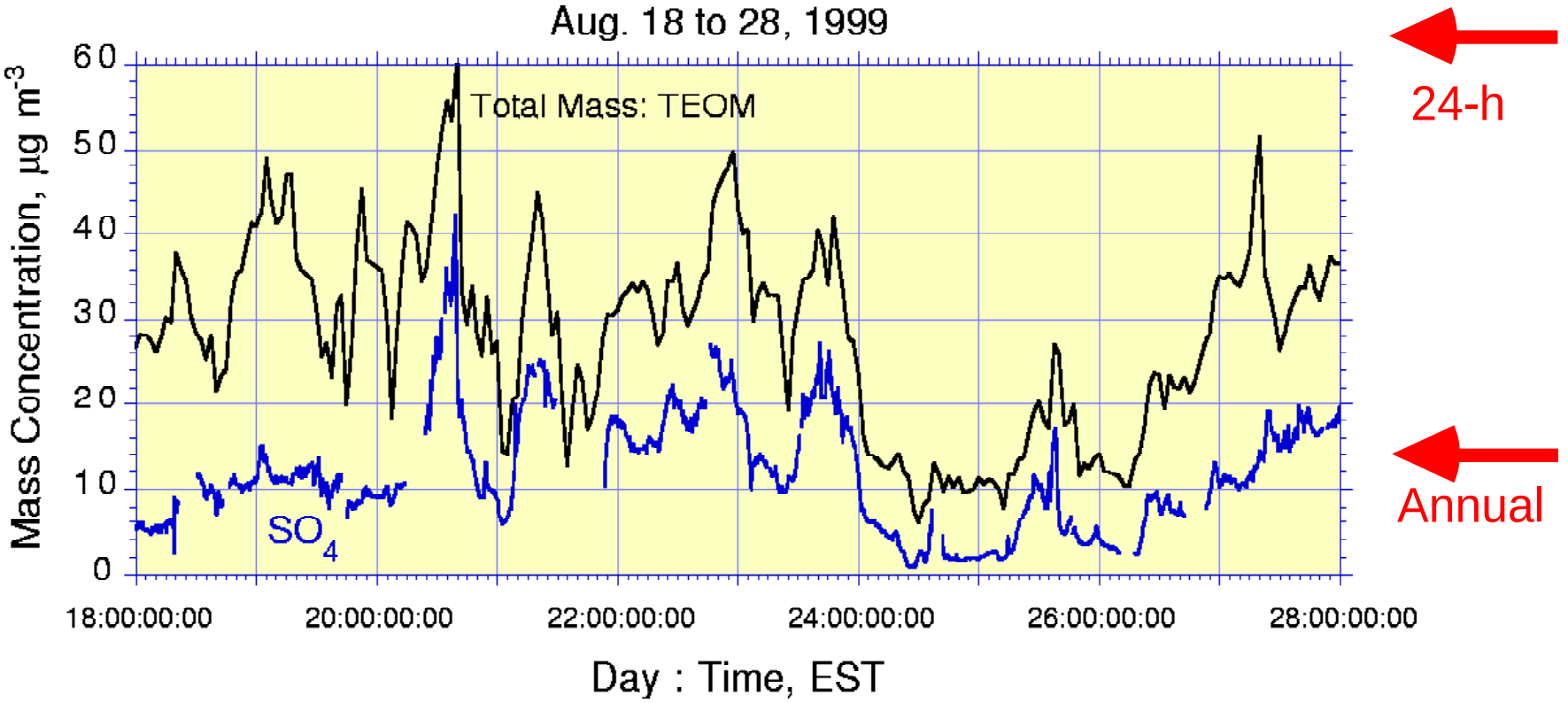
- Describe ***temporal variation*** of properties of ambient tropospheric aerosol:
  - Synoptic scale (days). Relate to frontal passage, air mass type, general buildup and decay of mass loading, change in properties ...
  - Subdiurnal scale (hours). Changes associated with breakup of nocturnal boundary layer, bursts of nanoparticles, changes in size, changes in composition ...

cont'd . . .

RAPID MEASUREMENT OF AEROSOL MASS AND SULFATE CONCENTRATION

Time resolution 4 minutes

Atlanta GA, summer 1999

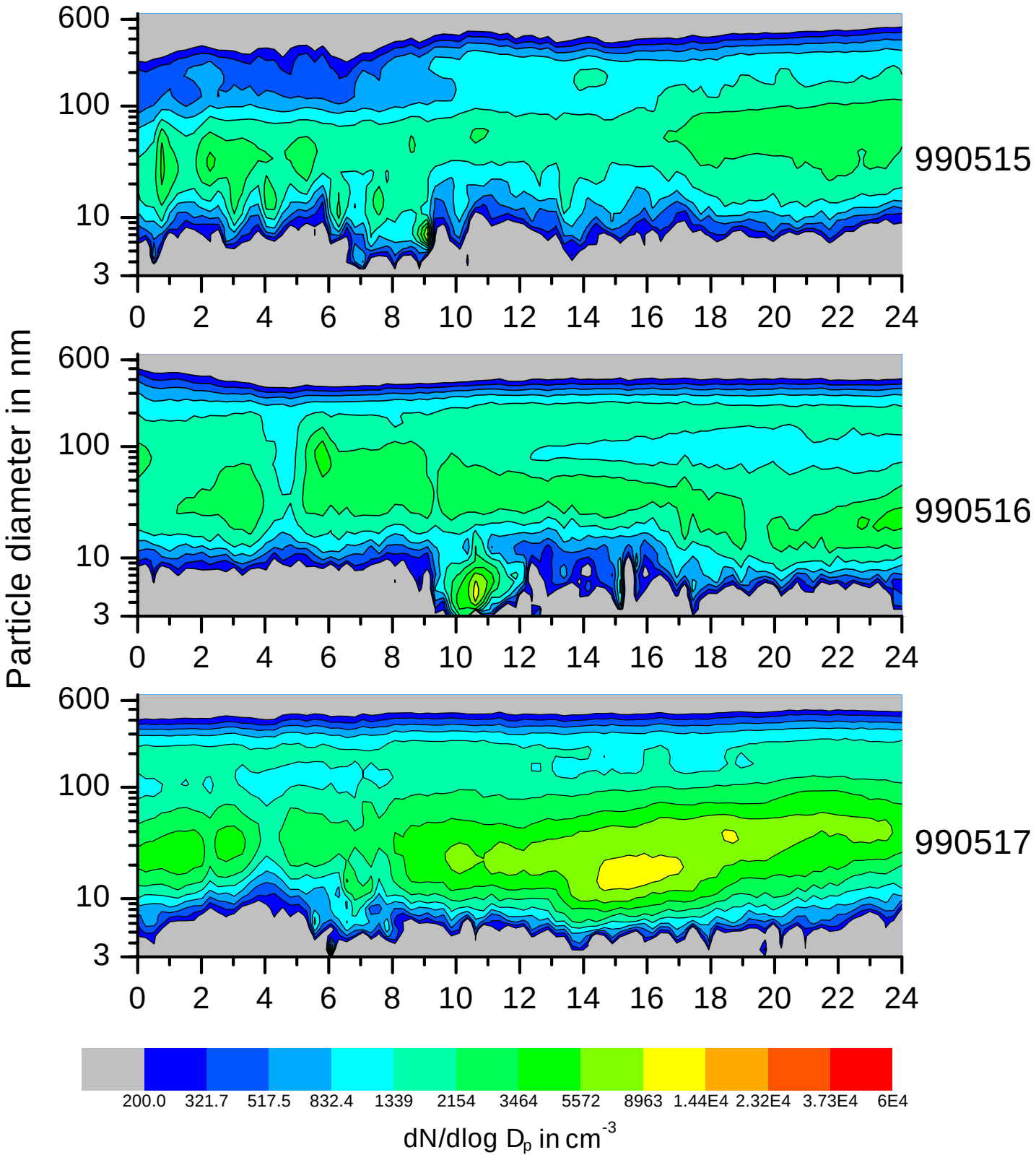


Y-N Lee (BNL), R. Weber (GaTech)

TIME DEPENDENT PARTICLE SIZE DISTRIBUTION

Differential Mobility Analyzer, Low Relative Humidity

Rural Germany, May, 1999. Time Resolution 10 min



F. Brechtel (BNL), W. Birmili (IFT, Leipzig)

Objectives of TAP Field Studies (*cont'd*)

- Describe ***temporal evolution*** of properties of ambient tropospheric aerosol on a subdiurnal scale (hours).
  - Full derivative
  - Partial derivative

$$\frac{dP}{dt} = \frac{\partial P}{\partial t} - v\frac{\partial P}{dx}$$

Measure

Desire

cont'd . . .

Objectives of TAP Field Studies (*cont'd*)

- ***Relate*** temporal evolution of properties of ambient tropospheric aerosol to chemical and physical processes:
  - Gas-phase chemistry: oxidants, sulfur, nitrogen, organics ...
  - Clear-air microphysical processes
  - Aqueous-phase reactions in clouds
  - Microphysical processes in clouds
- ***Characterize*** the three-dimensional field of aerosols and related atmospheric chemistry and meteorological variables (as function of time) sufficiently well to meet modelers' requirements for:
  - Initial and boundary conditions of model.
  - Measurement data base against which to compare the modeled picture of aerosol evolution.

Model-Based Interpretation of the Field Measurements

- Quasi-Lagrangian experiment imbedded in an Eulerian Framework
  - The model will be Eulerian--a "cubic meter model" imbedded in a 3-D transport model with parametrized turbulent mixing.
  - Minimize the advective term in the continuity equation by conducting measurements in a quasi-Lagrangian sense.
  - Array surface sites to take advantage of prevailing wind directions.

Meteorological Research Component

- The "cubic meter model" must be embedded in a state of the art meteorological transport model.
- There are many meteorological phenomena such as mixing, entrainment, deepening of boundary layer, vertical and horizontal mean transport and eddy diffusion that must be accurately accounted for in describing aerosol evolution and atmospheric chemistry generally.
- These requirements suggest the need for a meteorological research component to TAP
  - Not just a service function.
  - Not just providing 4DDA but participating in the analysis and interpretation of the observations in terms of the controlling meteorology.

Approach of TAP Field Studies

- Detailed characterization of aerosol at "Supersite"
  - Continuous in time -- provides temporal context for measurements.
- Less detailed characterization of aerosol at satellite sites
  - Continuous in time -- provides spatial and temporal context for measurements.
- Describe the evolution of ambient tropospheric aerosol on 200 km scale
  - Lagrangian or quasi-Lagrangian studies.
- **Other???**

TAP Science Team

- Scientists participating in TAP will be selected on the basis of proposals in response to DOE Program Announcements.
- Successful proposers will participate as TAP Science Team members to ensure that the program meets the broadest needs of the research community and the specific needs of the DOE Environmental Sciences Division.

Ramping up of TAP

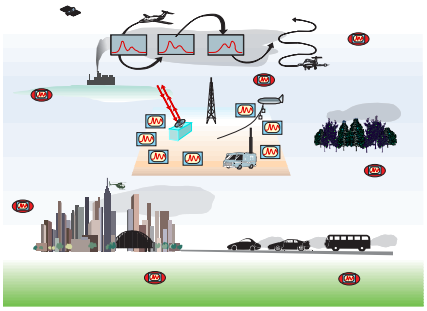
- Gradually populate the Science Team.
- Design the decade-long Program.
- Conduct pilot projects in coordination with other projects. Possiblities include:
  - Texas 2000 study, Houston, August-September 2000
  - Study in conjunction with ARM Aerosol IOP, Oklahoma
  - Central Valley California Study, Dec. 2000-Jan. 2001
  - Environmental Meteorology Program Salt Lake City study, Fall, 2001

TAP PRELIMINARY PROGRAM PLAN

DOE-SC-XXXX

Tropospheric Aerosol Program

Tropospheric Aerosol Program



Preliminary Program Plan

June 1999

U. S. Department of Energy
Office of Science
Office of Biological and Environmental Research
Environmental Sciences Division

Available on the web from the TAP home page . . .

http://www.tap.bnl.gov